The cooperative stations are nearer the crops, being mostly in small towns, or even on farms, in some instances, but they measure only rainfall and temperature once a day and have no self-recording instruments that keep a continuous record. Thus, for these which are more directly applicable, many weather phases are not available.

The crop statistics are even more hazy and generalized, in addition to being relatively inaccessible. We can find easily the estimated yield per acre or total acreage, for the most available data give these figures on a State unit basis, but yields often vary widely in different parts of a State. Local, even in most places county, temperature and rainfall data are available, but what about corresponding yield figures? They are to be had in some individual State publications, but a complete file for one State is difficult to find outside the issuing office and then the series is rarely carried back far enough to be of material value for study purposes. Even if county figures were more readily available, we are again handicapped by the lack of detail, only yield per acre and total acreage being given.

If we are studying corn, for example, when was the crop planted, when did it first appear above ground, when were first leaves seen, when was it knee-high and waist-high, when did ears first appear, silking, tasseling, when in milk, dough, and early roasting-ear stages, when mature? Are there any answers to these important questions? Maybe, locally, at certain experiment stations or elsewhere, but are these records continuous for the same crop under the same cultural practices for 25 years, or more?

The problem at present is to account for the 40 per cent divergence between the predicted and actual yields. Assuming we have carried our study to the 0.90 coefficient mark, and that phenological data in sufficient detail are available for 25 years, what about weather data in corresponding detail? These should be available for at least the neighborhood of the growing crops. At most State experiment stations, unless unusually well equipped, there are maximum and minimum thermometers and a rain gage. These are read at about 4 p. m. or 8 a. m. and the maximum and minimum temperature, set maximum temperature, and total rainfall entered on forms. Where are the details? How much sunshine, what was soil temperature, when did rain occur, how long were temperatures above or below a significant value, what was the relative humidity, rate of evaporation, etc.?

Even if the above questions were satisfactorily answered how can we be sure that we have everything we need? Maybe we need leaf temperature, intensity of solar radiation, plant transpiration, moisture of the soil at different depths, and many other details too numerous to mention.

CONCLUSION

Are we doing everything possible to facilitate the study of crop production in its relation to the weather on a large scale, or even in local areas? There have been some beginnings. Some phenological studies have been made here and there, notably those of Thomas Mikesell, but only in very localized sections. The State weather and crop service of Iowa is at present engaged in collection of phenological data, but the records are still short. There are, at present, no known systematic researches being conducted of the direct relation of weather to crops under field conditions, where detailed weather and crop data are collected, side by side.

We breed high yielding corn, wheat, and oats, drought-resistant corn, rust-resistant wheat, etc., but too little is known of the effect of weather on crops in their various stages of development. We know hot, dry weather hurts wheat at heading time and corn when tasseling and some other generalizations, but that largely comprises the extent of our knowledge at present.

To enable us to know just how the weather is affecting a crop at any time, to forecast crops accurately, and to practice agricultural meteorology as a science and not as an art, we need accurate and comparable data of weather and of crop progress, with the details of various weather phases and of crop development from planting to harvest accurately observed and recorded on the ground.

TOR BERGERON'S ÜBER DIE DREIDIMENSIONAL VERKNÜPFENDE WETTERANALYSE [1]

By ERIK BJORKDAL

[Translated from German text by Andrew Thomson]

Translator's note.—This large and important work of 110 pages (31 by 23 centimeters) with 6 plates and 25 figures written by Doctor Bergeron of the Norwegian Meteorological Office at Oslo constitutes the most important recent summary of the technique of the Norwegian School of Meteorology.

Due largely to the absence of definite guidance on how to locate "fronts" on the weather map, considerable misunderstanding of polar front methods has arisen. Prof. J. Bjerkness's memoir [2] on Practical Examples of Polar Front Analysis, written in 1926, deals with specific cases of fronts passing over the British Isles, whereas Doctor Bergeron discusses the general principles of frontology equally applicable to Europe and to North America.

The following illuminating review by Doctor Bergeron's colleague indicates the field covered by Doctor Bergeron's extremely valuable and suggestive book which is marred for English readers by an involved style of sentence structure:

This work gives the first systematic exposition of the analytical methods of the so-called Bergen School of Meteorology. It discusses the existence and formation of tropospherical air masses and air separations, as well as their decisive importance for weather. Until further empirical investigations have been carried out the results hold only during the winter season over North America, north Atlantic, and western Europe.

The author first attacks the view which has often been advocated that the chief seat of pressure variations and weather changes may be sought in the substratosphere. He brings forward various plausible reasons for believing that the extratropical transformations of energy have their seat essentially in the troposphere and even in its lower half. There the weather actually displays itself.

The study of the structure of the troposphere is thus of fundamental importance. Already before the work of the Bergen meteorologists, various investigators had deserted pure isobaric geometry and realized there was a battle between air masses. But none of them was lead from their theoretical considerations to the daily weather map and no one realized that the boundary surfaces were entities of which the properties and dynamics

[1] Bergeron, T.: Ueber die Dreidemensional Verknüpfende Watteranalyse, I. Teil. Geophys. Pub., Oslo, vol. 5, No. 6, 1928.
[2] Geophysical Memoir No. 50, British Meteorological Office, London, 1930.

could be studied. This was first done in the works of J. Bjerknes and H. Solberg.

The complete 3-dimensional weather analysis can be attained only by the utilization of the inner connections which exist between the fields of the meteorologist elements and between their singularities. Two-dimensional fields may be constructed from the ordinary continuously recorded data, but one must consider that the local and individual derivatives of the elements, without further information, can not be interchanged. The registrations show in addition that linear interpolation between adjacent air particles can be employed only within a homogenous air mass. With the passing of a front, linear interpolations can be employed no longer.

The analysis should be based only on representative observations. Representative temperature data should fulfill the condition that the mean vertical temperature gradient has approached already its characteristic value in the free air for the air mass under consideration. Frequently nonadiabatic influences disturb the temperatures at the earth's surface, so that they cease to be representative. Already in 1919 the Bergen school had adopted the view that temperatures of the free air and of mountain peaks should have special weight.

If the source and path of an air mass are known, then the internal changes during its transport can be estimated. Starting with the conditions in the area of origin one can judge the value of the characteristics of the air mass and of their height distribution along its path. In the first place, the approximately conservative properties must be considered; that is, those properties of which the intensity in any individual element of mass remain practically constant. Certain thermal and chemical properties belong to these classes.

Potential temperature and vertical temperature gradient are, with certain reservations, conservative. Admixtures of suspensions of particles so fine that they take part almost completely in the air movement presumably belong to the conservative chemical properties. These produce an opalescent turbidity of the air which has been investigated by the author at Swedish and Norwegian stations. Here the essential part of the pure opalescent turbidity arises out of desert or continental dust which has been transported northward from the subtropical high-pressure zone.

The breaking up of the troposphere into great currents appears markedly in winter through the striking great-scale features of the pressure field. In these currents the air masses concerned will be subjected to two fundamentally different types of exterior influences.

One mass which moves over the ocean toward an always increasing warmer understratum will increase its entropy. On the other hand, an air mass which goes over the ocean with ever colder surface temperatures loses entropy. Thus two chief types of air mass are probable, which are designated by the terms "cold-air mass" and "warm-air mass." Of these chief types, "polar air" and "tropical air" are the most important representatives.

The cold air mass will be formed mostly in polar areas and in winter generally in the continental anticyclones of higher latitudes. It is in its area of origin, cold, dry, and especially at lower levels stabile. It moves in general Equatorward so that the difference between air temperature and sea temperature is negative. The entropy supply exerts its greatest effects on the lowest layers of the air, which experience an increase of potential temperature and of vertical temperature gradient.

Experience has shown that after the cold air mass has traveled for about 200 kilometers over distinctly warmer ocean it has already taken up sufficient moisture that its humid air content is brought over the condensation level. Cu-Nb clouds with anvil form and even slight precipitation occur. On account of lively up and down movements definite clearings and pieces of clear sky may be observed. Because of the great turbulence any fog which happened to be present can only persist in small zones where it appears below a temporary calm. The system of hydrometeors can be characterized as belonging to shower air.

The warm air mass is usually generated in the oceanic highs of the Tropics and in summer over every great snow-free and ice-free land surface. It is in its area of origin warm—in the case of continental air also dry—and stratified approximately according to its radiation equilibrium. On the average it moves poleward so that the difference in temperature of the air and the land or ocean over which it travels is positive or zero. The entropy losses affect most strongly the lowest layers, which experience a reduction of vertical temperature gradient. The upward transport of humidity will be a minimum and the slight heat transport will be directed downward. The potential temperature will exhibit slight change.

Various cooling effects give rise to stratiform cloud and to fog, which on account of the small convection persists without dissipation. The warm air mass exhibits pervading bad visibility because of the tendency for fog formation. The system of hydrometeors can be characterized as belonging to drizzle air.

The direct empirical grounds for the properties of the air masses described can be supplied only through exhaustive synoptical research. This will be the work of the second part. Part I already deals statistically with the relation between the probable air masses and the difference between air and sea temperatures, vertical temperature gradient, and hydrometeors.

The temperature difference is investigated from the data of Dutch lightships and the dependence on origin of air mass confirmed.

The aerological airplane ascents at Berck, near Boulogne, 1918–19, give good reasons for believing that shower air and drizzle air are of fundamentally different structure. For the same surface temperature, there was a temperature difference of 9° C. of the two masses at 3 kilometers height. In drizzle air the chief condensation layer was about 1 kilometer above the ground, above which the humidity fell rapidly. In shower air no sharply bounded chief layer of condensation existed, while above 3 kilometers the relative humidity was distinctly greater than in drizzle air.

Several observations in Berck support the author's theory that the coming together of thick and compact water clouds with layers of permanent ice crystals is, except for drizzle, a chief source for all usual precipitation.

Conclusions may be deduced from the kind of hydrometeor regarding the thermodynamics and dynamics of the classified air mass. In the author's opinion the following threefold grouping of hydrometeors recommends itself for adoption in international observation technique:

(1) Ordinary rain (snow)—Either ordinary raindrops (snowflakes) or scanty fine droplets.

(2) Drizzle—Exclusively very fine droplets with great number of drops per unit volume.

(3) Showers—Sharp intermittency of precipitation and medium cloud cover.

From a consideration of the mode of formation of cold air and warm air masses it could be expected that a positive difference between air and sea temperatures corresponds to drizzle and a negative difference to shower air. The author has investigated this rule from 620 observations taken at Thorshavn and found that the rule holds good without exception for differences greater than 0.5° C. For smaller differences no definite contradiction could be established. It thus follows that accurate measurements of air and sea temperatures at all international island and ship stations and their report to 1/10° C. or 1/5° F. have great importance for practical weather analysis.

The investigations of the author on horizontal visibility in Scandinavia confirmed the hypothesis that the opalescent turbidity of the warm air mass is notably greater than of the cold air mass.

From a previous work of the author (Wellen und Wirbel, Leipzig, 1924) it is known that surfaces of equal entropy (isentropic surfaces) of the cold mass are inclined upward toward the pole, while in the warm air mass they are almost horizontal. Thus is follows, as is later discussed in detail, that the cold mass easily becomes heterogeneous while the warm air mass with horizontal isentropic surfaces is among the most homogeneous masses of the atmosphere.

By means of aerological data from Holland and Spieglitzer, Schneeberg, the existence of at least two separate air masses is statistically indicated. The potential temperature has at any level two pronounced frequency maxima which correspond to polar air and tropical air.

When two air masses each uniformly homogeneous approach each other nearer than about 1,000 kilometers, the area between them no longer fulfills the conditions of a homogeneous air mass. A frontal zone occurs which can gradually sharpen to a front. Fronts are narrow inclined transition zones of the same vertical extent as the air masses. It is essential that the difference of the values on both sides of the front of at least one of the independent elements (temperature, pressure, wind, humidity) is so great that it has an appreciable effect on the great scale dynamics (of the air mass).

In the troposphere, fronts are continuously produced and destroyed. The author has called these processes frontogenesis and frontolysis. Kinematic frontogenesis consists in the coming together of the equiscalar surfaces of an element through the motion of the individual particles.

In dealing with air masses which are not too extended the field of movement can be treated as linear. The movement itself may be resolved into four partial fields consisting of a translation, a rotation, an expansion, and a deformation. Only through the deformation movement can two particles essentially approach or separate from one another.

As no essential change of volume can occur, a deformation is undergone either as an extension along the principal axis and a contraction along both secondary axis or as a contraction along the principal axis and an extension along the secondary axis. Material particles which at one time form a plane surface will always form a plane surface which during movement alter only their orientation and their distance from the field's center. In a 2-dimensional field the surfaces rotate so that they will ultimately be perpendicular to the axis of greatest contraction.

A symmetrical deformation field with vertical axis produces the following effects—the extension of the principal axis causes dissolution of horizontal inversion zones while contraction brings sharpening.

A 2-dimensional half deformation field with one horizontal axis and an axis directed obliquely upward causes frontogenesis and dissolution of inversions. Contraction along the horizontal axis causes frontolysis, while expansion causes inversion formation.

The choice of entropy surfaces as equiscalar surfaces presupposes advective frontogenesis. Thus from the beginning the entropy surfaces are inclined and advection comprises a permanent deformation-field of which the axis of contraction can not be directly vertical. It thus follows, as has been previously pointed out, that in the warm air mass where the isentropic surfaces are almost horizontal almost no frontogenesis occurs; in the cold mass where they are somewhat inclined, weak frontogenesis; and in frontal zones where they are considerably inclined there is effective frontogenesis.

The general circulation of the earth's atmosphere is divided into several partial circulations. They can be considered as a system of vertical wheels and of horizontal wheels. The hyperbolic points between the wheels are the centers of the deformation fields in the foregoing sense. Frontogenesis and frontolysis develop in the areas between the parts of the general circulation. The effect of the vertical wheels and horizontal wheels will alternately strengthen and oppose each other.

When the general circulation works frontogenetically, areas occur where by preference fronts are formed. The favored frontal zones run east and west. In the intermediate zone where the vertical opposes the horizontal circulation, the resulting effect will be mostly frontolysis so that the air exchange between pole and Equator can go on unhindered.

Doctor Bergeron's book is conceived as the principle introduction to the problem of air masses and front formation. The use of the results for investigating the relations actually occurring in the troposphere will be shown in Part II. The wish may be expressed that we may not need to wait long for this continuation.

ON PERIODICITY IN SERIES OF RELATED TERMS [1]

By SIR GILBERT WALKER, F. R. S.

SUMMARY

In 1927 Yule developed the idea that a series of numbers $u_1, u_2, \ldots, u_n$ expressing the condition of a physical system, such as successive annual sun-spot numbers, might be regarded as due to a series of accidental disturbances from outside operating on some dynamical system with a period or periods of its own, probably subject to damping. The consequent oscillations would vary both in amplitude and in period. In this paper it is shown that if Yule's equation defining the relationship between successive undisturbed terms of the u series is

$$u_u = g_1 u_{x-1} + g_2 u_{x-2} + \ldots + g_s u_{x-s},$$

then, provided n is large, a similar equation holds very approximately between successive values of r_p, the correlation coefficient between terms of u separated by p intervals, i. e.,

$$r_x = g_1 r_{x-1} + g_2 r_{x-2} + \ldots + g_s r_{x-s}.$$

[1] On periodicities in series of related terms, Proc. Roy. Soc. Series A, vol. 131, No. 818, pp. 518-532.

* The subject is treated from the mathematical viewpoint and since no one's views are entitled to greater consideration than those of Sir Gilbert we print in his own words the summary of his conclusions.—ED.